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Title: OPERATIONAL SPECIFICATIONS OF THE L.I.T.E.S. (LASER ILLUMINATED TRACK ETCH SCATTERING) DOSIMETER READER

(Full paper and overhead slides)

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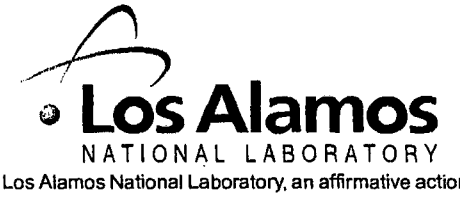

OPERATIONAL SPECIFICATIONS OF THE L.I.T.E.S. (LASER ILLUMINATED TRACK ETCH SCATTERING) DOSEMETER READER

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OPERATIONAL SPECIFICATIONS OF THE L.I.T.E.S. (LASER ILLUMINATED TRACK ETCH SCATTERING) DOSEMETER READER

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The Personnel Dosimetry Operations Team at the Los Alamos National Laboratory (LANL) has accepted the LITES dosimeter reader into its suite of radiation dose measurement instruments. The LITES instrument transmits coherent light from a HeNe laser through the pertinent track etch foil and a photodiode measures the amount of light scattered by the etched tracks. A small beam stop blocks the main laser light, while a lens refocuses the scattered light into the photodiode. Three stepper motors in the current LITES system are used to position a carousel that holds 36 track etch dosimeters. Preliminary work with the LITES system demonstrated the device had a linear response in counting foils subjected to exposures up to 50 mSv (5.0 rem). The United States Department of Energy requires that annual general employee dose not exceed 50 mSv (5.0 rem). On a regular basis, LANL uses the Autoscan 60 reader system (Thermo Electron Corp.) for counting track etch dosimeters. However, LANL uses a 15 hour etch process for CR39 dosimeters, and this produces more and larger track etch pits than the 6 hour etch used by many institutions. Therefore, LANL only uses the Autoscan 60 for measuring neutron dose equivalent up to exposure levels of about 3 mSv (300 mrem). The LITES system has a measured lower limit of detection (LLD) of about 0.6 mSv (60 mrem), and it has a correlation coefficient of $R^2 = 0.99$ over an exposure range up to 500 mSv (50.0 rem). A series of blind studies were done using three methods: the Autoscan 60 system, manual counting by optical microscope, and the LITES instrument. A collection of track etch dosimeters of unknown NDE (neutron dose equivalent) were analyzed using the three methods, and the (PC) performance coefficient was calculated when the NDE became known. The Autoscan 60 and optical microscope methods had a combined PC = 0.171, and the LITES instrument had a PC = 0.194, where a PC less than or equal to 0.300 is considered satisfactory.

INTRODUCTION

In a previous paper [1], the authors described their preliminary work and also the past research by other investigators foundational in the development of the LITES (Laser Illuminated Track Etch Scattering) dosemeter system at LANL (Los Alamos National Laboratory).

The current US Department of Energy (DOE) regulations specify general employee annual exposure to annually not exceed 50.0 mSv (5 rem)[2], and LITES was designed to satisfy the US DOE Laboratory Accreditation Program[3,4] (DOELAP) for Personnel Dosimetry requirements for neutron dosimetry, to measure neutron dose equivalent (NDE) up to 50.0 mSv (5 rem). (Author's note: The U.S. DOE documents specify dose equivalent in terms of "rem", hereafter units of neutron dose equivalent in SI units will be used.)

After publication of the paper describing the beginning LITES work at Los Alamos and the Georgia Institute of Technology, H.J. Gepford relocated to the University of Missouri at Rolla and continued further work there. Two LITES-type instruments were constructed used and tested, one at Los Alamos and the other at Rolla. The instrument developed at Rolla has since been moved to Los Alamos.

LITES SYSTEM DESCRIPTION SUMMARY

As a point of review, the functionality of the LITES system is portrayed in the enclosed schematic (Figure 1). About 10% of the full power of the 10 mW He-Ne laser is diverted with a optic window to a photodiode to measure total laser power output. The

remaining 90% of the laser light is transmitted through the track etch detector (TED), where the pits caused by proton recoil damage scatter the incident laser light. A rigid steel rod beam stop blocks most of the laser light from the photodiode. In the LITES system, the ratio between the scattered laser light and the magnitude of the reference laser power is the primary operational parameter for measuring the neutron dose equivalent (NDE) with the track etch detectors.

Both of the LITES instruments use an automated motion control table on an XZ two dimensional axis to move the TED across the incident laser beam. The diameter of the laser beam at the TED location is about 1.0 mm, while the laser spot diameter is about 0.5 mm at the beam stop location. The LITES system steps the TED across the laser beam spot in 1.27 mm increments. This is compared to the overall rectangular dimensions (25 mm * 20 mm) of the TED. At LANL, the active effective sample area of the TED is restricted to an area of 10.0 mm * 10.0 mm in order to avoid edge effects and a commonly occurring region of TED surface damage due to uneven heat transfer effects in the liquid chemical etch process. The Los Alamos etch protocol uses with a one hour pre-etch in a 60% methanol and 40% 6.25 N NaOH solution at 70 degrees C to remove alpha and heavy charged particle tracks. This was followed by a 15 hour etch in 6.25 N NaOH maintained at 70 degrees C during the etch cycle. A ten-minute stop etch using room temperature 0.1 N HCl and a final rinse with distilled water and a wetting agent completed the protocol. The etch protocol resulted in an average track diameter of 20 μm for bare ^{252}Cf tracks.

One of the LITES devices has a more advanced motion control system than the other, where a large carousel capable of holding 36 track etch detectors has been

integrated into the system. An automatic reading of these 36 TEDs takes about 20 minutes, but this time period does not include the optical cleaning and loading of the TEDs into the carousel.

LITES OPERATIONAL SPECIFICATIONS

The default operational TED reader at Los Alamos is the Thermo Electron Corp. Autoscan 60 machine. However, LANL uses a 15 hour etch process for CR39 dosimeters, and this produces more and larger track etch pits than the 6 hour etch used by many institutions. In addition, the Autoscan 60 has a non-linear response to these larger pits produced in the 15 hour etch. Figure 2 illustrates this in a plot[5] of the number of track etch pits counted versus the known exposure on track etch dosemeters. LANL only uses the Autoscan 60 for measuring neutron dose equivalent up to exposure levels of about 3 mSv and LITES is used for measuring NDE levels up to 50 mSv.

The LITES instrument developed at the University of Missouri at Rolla has a measured lower limit of detection (LLD) of 0.3 mSv using the method specified by the US Department of Energy[4]. However, the LITES system developed at LANL has only been able to produce a measured LLD of 0.6 mSv. In the enclosed plot, Figure 3, the number of illuminated areas (I.A.) is plotted versus the measured lower limit of detection (LLD). The LITES motion control system sequentially steps the focused laser beam spot across the face of the CR-39 TED in a checkerboard type pattern. As the I.A. number is increased, the measured LLD decreases, until a minimum in the LLD is reached at 12 I.A.s. This result is unique for the set of CR-39 TEDs used in this test. As seen in Figure 3, the measured LLD increases when the I.A. number is increased up to 25. It is

suspected that this happens when more total area is included in the analysis, and more anomalous areas on the TEDs are 'seen' by the LITES system. This effect is a question of ongoing investigation, leading to a possible modification in the LITES statistical method.

A series of blind studies used three instruments, the Autoscan 60 system, manual counting by optical microscope, and the LITES instrument in a comparison of performance coefficient (PC) determination[3]. A collection of track etch dosimeters of unknown NDE (neutron dose equivalent) were analyzed using the three devices, and the PC was calculated when the NDE values became known. The Autoscan 60 and optical microscope methods had a combined PC value equal to 0.171, and the LITES instrument had a PC value equal to 0.194, where a PC less than or equal to 0.300 is considered satisfactory.

References

1. Moore, M.E., Gepford, H.J., Hermes, R.E., Hertel, N.E., Devine, R.T., *Laser Illuminated Etched Track Scattering (LITES) Dosimetry System,* Radiat. Prot. Dosim. **101**(1-4), 43-45 (2002).

2. Federal Register, Vol. 58, No. 238, Tuesday December 14, 1993, Rules and Regulations, pp. 65489

3. "Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems" Handbook. DOE/EH-0026, Dec. 1986

4. "Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems" Handbook. DOE/EH-0027, Dec. 1986

5. 14th Annual Users' Group Meeeting, Thermo Electron Corporation, September 2003, www.thermo.com/rmp

List of Figures

Fig. 1 Schematic of LITES system

Fig. 2 Response of the Autoscan 60 system to CR-39 TEDs etched to 15 hours

Fig. 3 Number of illuminated areas versus the measured lower limit of detection

Fig. 4 High dose response of the LITES system to CR-39 TEDs etched at 6 hours.

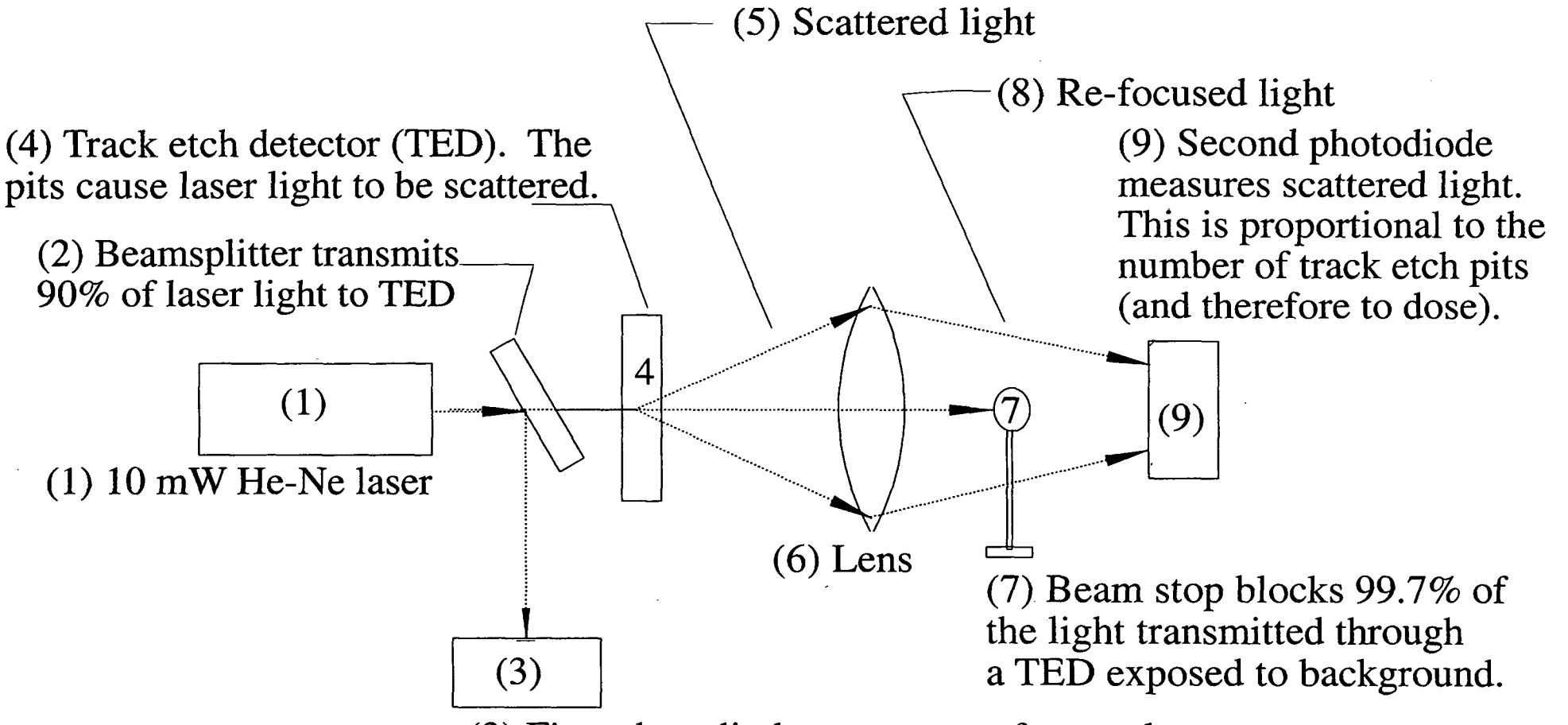
Software Specifications for Text and Figures

Fig. 1 lites2.skf, Software, Autosketch Rel. 6, AutoDesk Inc.

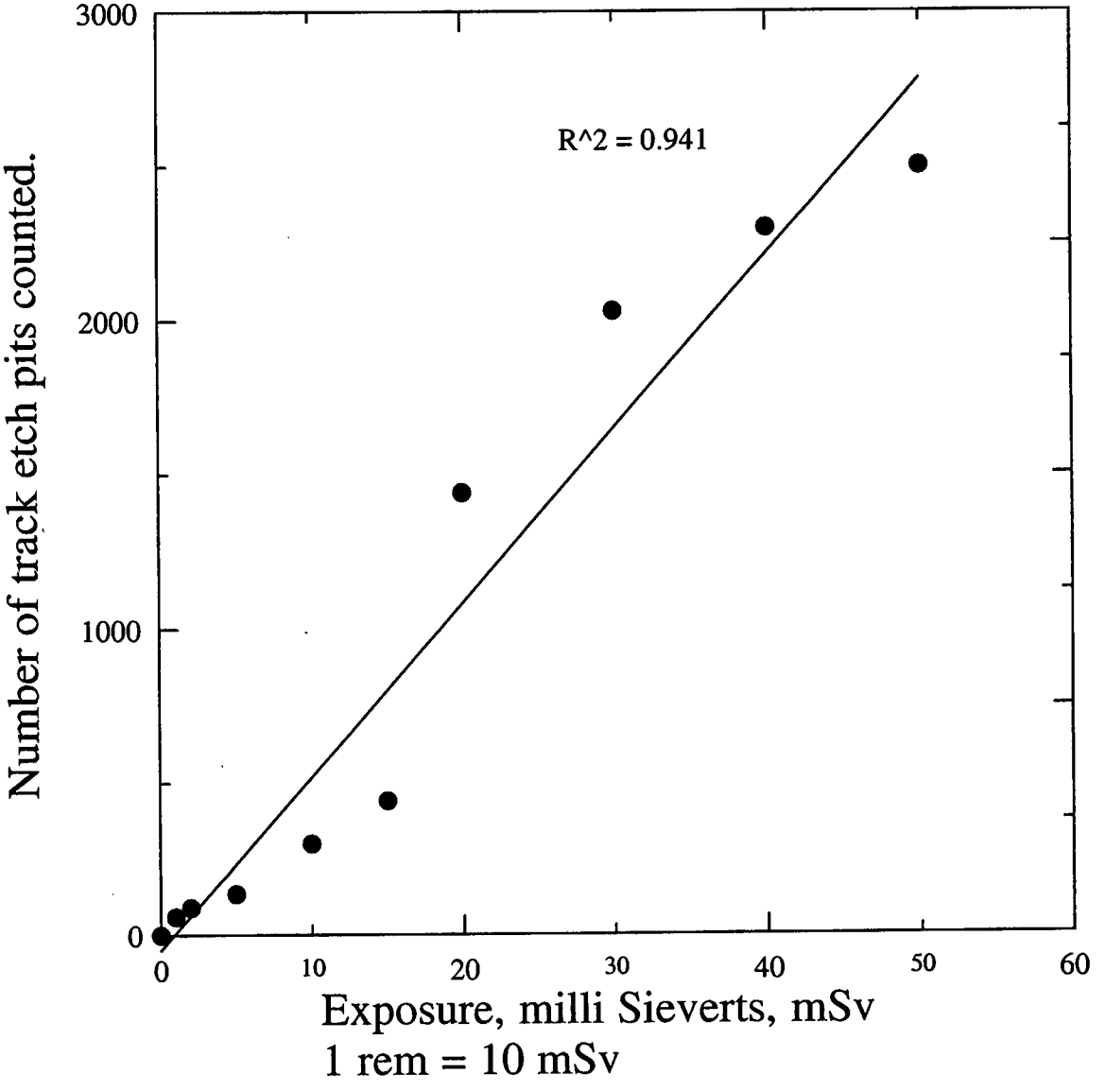
Fig. 2 autoscan.grf, Software: Grapher 2.03, Golden Software Inc. 1999

Fig. 3 LLD_vs_illum_areas.grf, Software: Grapher 2.03, Golden Software Inc. 1999

Fig. 4 High_Dose_6_hour.grf, Software: Grapher 2.03, Golden Software Inc. 1999

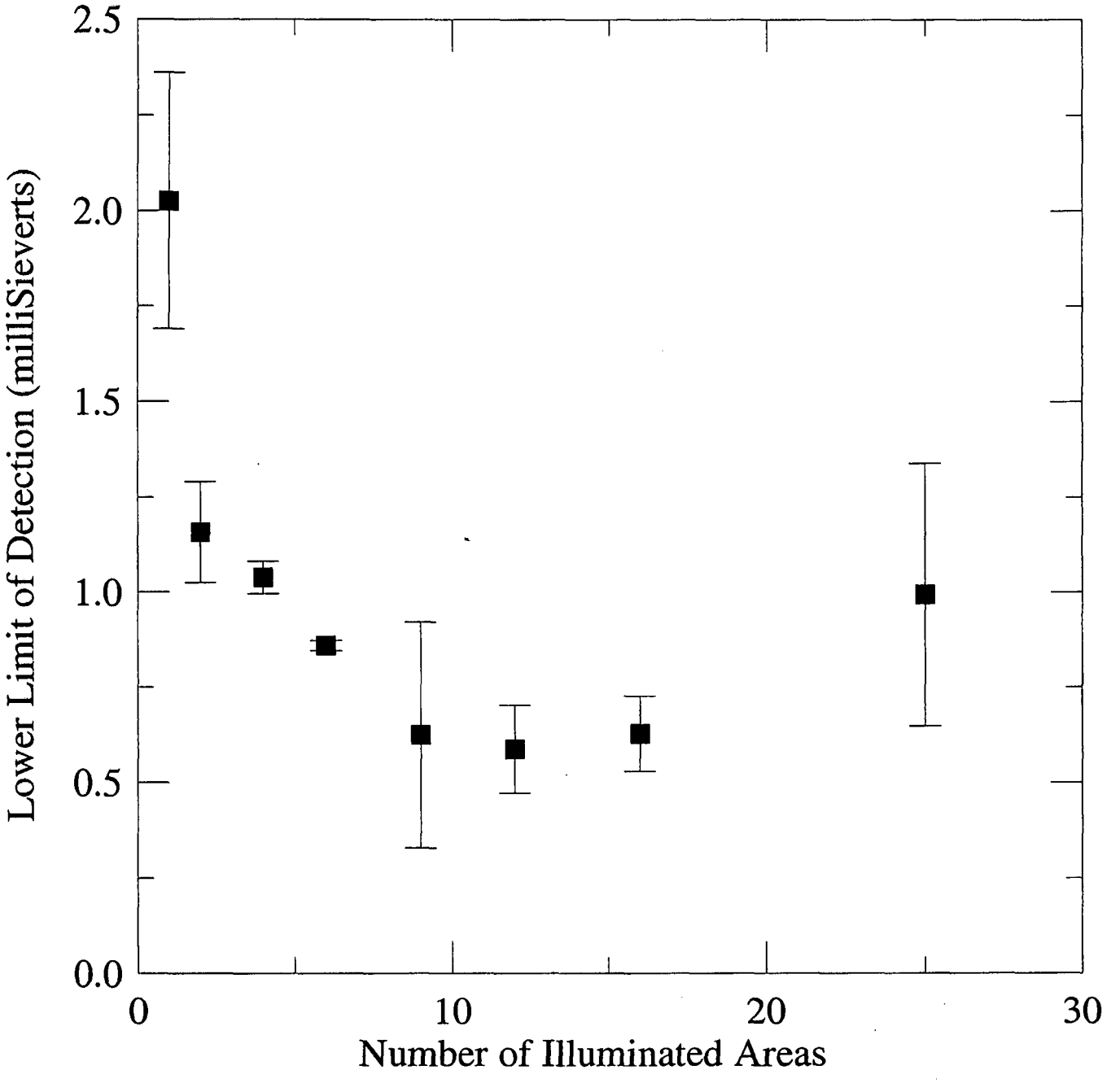

(5) Scattered light
(8) Re-focused light
(4) Track etch detector (TED). The pits cause laser light to be scattered.
(9) Second photodiode measures scattered light. This is proportional to the number of track etch pits (and therefore to dose).
(2) Beamsplitter transmits 90% of laser light to TED
4
(1)
7
(9)
(1) 10 mW He-Ne laser
(6) Lens
(7) Beam stop blocks 99.7% of the light transmitted through a TED exposed to background.
(3)
(3) First photodiode measures reference laser power.

lites3.skf



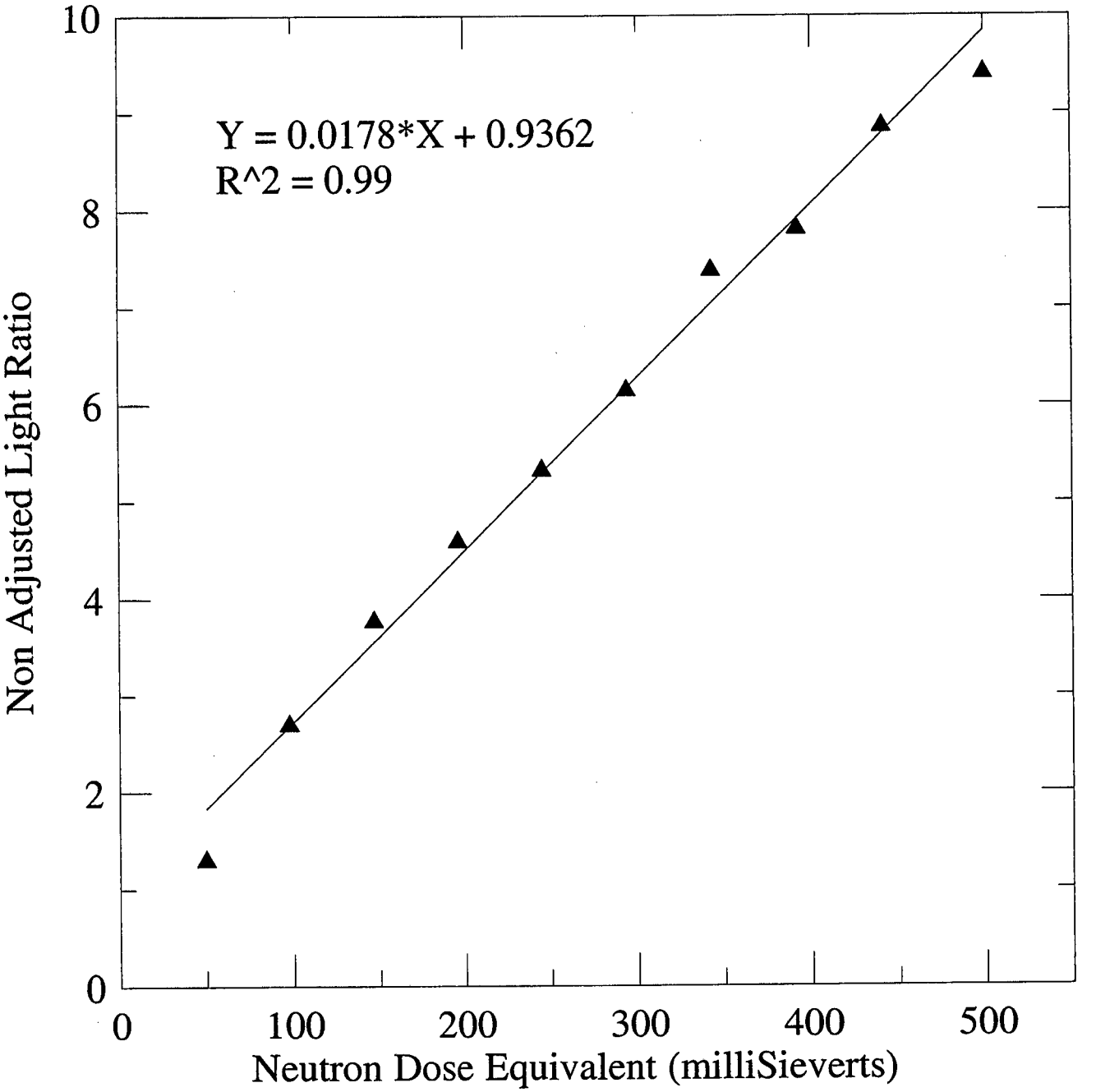
Calibration foils counted in Autoscan-60 system.
Counting saturates at about 15 mSv exposure.
The higher exposures are estimated with correction algorithms.

autoscan2.grf



LITES uses a sequential stepping in a checkerboard pattern to compute an average measured neutron dose equivalent (NDE) for each track etch detector. An increase in the number of areas illuminated by the HeNe laser produces a better measure of NDE, and therefore produces a lower measure of LLD.

LLD_vs_illum_areas.grf



High dose response of LITES to CR-39 track etch detectors etched at 6 hours.

High_Dose_6_hour.grf (Sheet1)